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RESEARCH MEMORANDUM

SPIN AND RECOVERY CHARACTERISTICS OF A MODEL OF A FIGHTER TYPE OF AIRPLANE WITHOUT A HORIZONTAL TAIL AND HAVING EITHER A SINGLE VERTICAL TAIL OR TWIN VERTICAL TAILS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on a model of a fighter type of airplane without a horizontal tail and having either a single vertical tail on the fuselage or twin vertical tails on sweptback wings.

The investigation indicated similar spin and recovery characteristics for either tail configuration tested at a given mass distribution. For a mass distribution chiefly along the wings, the vertical tail surfaces were not adequate for recovery from the spin. When the mass was distributed chiefly along the fuselage, however, either vertical-tail configuration, when in a rearward position, was effective in satisfactorily terminating the spin.

INTRODUCTION

Because of interest recently shown by aircraft designers in the relative merits of single- and twin-vertical-tail configurations on fighter types of airplanes having no horizontal tail, an investigation has been conducted in the Langley 20-foot free-spinning tunnel to compare the spin and recovery characteristics of several configurations of a swept-wing model of such an airplane. The investigation included tests of the model with either a single vertical tail mounted on the rear of the fuselage or with twin vertical tails mounted on the wings. The investigation also included tests of the model when loaded either chiefly along the wings or chiefly along the fuselage.

SYMBOLS

b	wing span, feet
S	wing area, square feet
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-feet square
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slugs per cubic foot
μ	airplane relative density $\left(\frac{m}{\rho Sb}\right)$
α	angle between fuselage reference line and vertical (approx. equal to absolute value of angle of attack at plane of symmetry), degrees
ϕ	angle between span axis and horizontal, degrees
V	full-scale true rate of descent, feet per second
Ω	full-scale angular velocity about spin axis, revolutions per second

APPARATUS AND METHODS

Model

A model of a swept-wing fighter airplane having no horizontal tail, used for the current investigation, was so constructed that it could be tested with either a single vertical tail mounted on the rear of the fuselage or twin vertical tails mounted on the wings. The twin vertical tails mounted on the wings were located at the inboard end of the wing control surfaces (approximately 44 percent out on the wing semispan).

The area of each of the twin vertical tails was equal to the area of the single vertical tail but the tail length for the twin tails was approximately one-half the tail length of the single tail. Thus the tail volume (area of surface times tail length), a convenient method for comparing tails in normal flight, was approximately equal for each tail configuration.

Three-view drawings of the model with the single vertical tail mounted on the rear of the fuselage and twin vertical tails located on the wings are presented in figure 1. A photograph of the model with the single vertical tail mounted on the fuselage is presented in figure 2. For some of the tests, the tail volume was increased by approximately one-third by moving the tails rearward as shown in figure 3. Table I presents the full-scale dimensional characteristics of a corresponding airplane if the scale of the model is assumed to be 1/20.

Lateral and longitudinal controls were combined in one pair of control surfaces called elevons. Longitudinal control was obtained by deflection of the elevons in the same direction and lateral control was obtained by deflection of the elevons differentially. Hereafter, in this paper, elevon deflections for longitudinal and lateral control will be referred to, for simplicity, as elevator and aileron deflections, respectively.

The model was ballasted by the installation of lead weights to obtain dynamic similarity to a corresponding airplane spinning at an altitude of 15,000 feet ($\rho = 0.001496$). A remote-control mechanism was installed in the model to actuate the rudder control for spin-recovery attempts. Sufficient moment was exerted on the rudder control to move the surfaces fully and rapidly to the desired position.

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in reference 1 for the Langley 15-foot free-spinning tunnel. The models, however, are now launched by hand with spinning rotation into the vertically rising air stream rather than being launched from a spindle. The airspeed is adjusted until the drag of the model balances the weight and, after a number of turns in the established spin, recovery is attempted by moving one or more controls by means of the remote-control mechanism. After recovery, the model dives into a safety net. A photograph of a model spinning in the test section of the tunnel is shown in figure 4.

The spin data presented herein were obtained and converted to corresponding full-scale values as described in reference 1. The turns for recovery were measured from the time the controls were moved to the time the spin rotation ceased. For recovery attempts in which the model struck the safety net while it was still in a spin, the recovery was recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net as, for example, > 3. A greater-than-3-turn recovery does not necessarily indicate an improvement over a greater-than-8-turn recovery. For recovery attempts in which the model did not recover in fewer than 10 turns, the recovery was recorded as ∞. When the model, after being launched with forced rotation into a spin, ceased rotation without movement of controls, the result was recorded as a "No spin" condition.

In accordance with standard free-spinning-tunnel test procedure, tests were made to determine the spin and recovery characteristics of the model at the normal spinning control configuration (elevators full up, ailerons neutral, and rudder full with the spin) and at various other aileron-elevator control combinations including zero and maximum settings of the surfaces for various model configurations. Recovery was generally attempted by rapid full rudder reversal. As is customary, tests were also performed to evaluate the possible adverse effects on recovery of small deviations from the normal spinning control configuration. For these tests, the ailerons were set at one-third of the full deflection in the direction of slower recoveries and the elevators were set at full up or two-thirds of their full up deflection whichever would cause slower recoveries. Recovery was attempted by rapidly reversing the rudder from full with to only two-thirds against the spin or by simultaneous rapid rudder reversal from full with the spin to two-thirds against the spin and movement of the elevators down, the latter method being used particularly when the model loading was chiefly along the wings, a loading for which elevators are often effective in terminating the spin (reference 2). This particular control configuration and manipulation is referred to as the "criterion condition." Recovery characteristics of the model are considered satisfactory if recovery from this condition requires $2\frac{1}{4}$ turns or less. This value has been selected on the basis of full-scale airplane spin-recovery data that are available for comparison with corresponding model test results.

PRECISION

The data obtained from the model tests are believed to be accurate within the following limits:

α, degrees	± 1
ϕ, degrees	± 1
V, percent	± 5
Ω, percent	± 2
Turns for recovery (from motion-picture records)	$\pm\frac{1}{4}$

Comparison between spin-recovery results of airplanes and corresponding models (reference 3) indicates that spin-tunnel results are in agreement with full-scale spin-recovery results about 90 percent of the time and that, even in the other 10 percent of the time, some indication of full-scale spin and recovery characteristics can be obtained.

The limits of accuracy of the measurements of the mass characteristics are believed to be:

Weight, percent	±1
Moments of inertia, percent	±5

The controls were set with an accuracy of ±1°.

Because of small inadvertent changes during testing, the measured weight and mass distribution of the model may have varied by as much as the following amounts:

Weight, percent	1 low to 2 high
Moments of inertia:	
I_X, percent	5 low to 12 high
I_Y, percent	5 low to 10 high
I_Z, percent	5 low to 6 high

TEST CONDITIONS

Table II presents the full-scale mass characteristics and inertia parameters of a corresponding airplane. The inertia parameters are plotted in figure 5 which can be used as an aid in predicting the effects of controls on spin and recovery characteristics as discussed in reference 2.

The normal control deflections used for the current tests were:

Rudder, degrees	30 right, 30 left
Elevons, degrees:	
As elevators	20 up, 10 down
As ailerons	15 up, 15 down

A few tests were also conducted with the elevators set at 25° up.

Intermediate control deflections used were:

Rudders, two-thirds deflected, degrees	20
Elevons, degrees:	
Deflected as ailerons, one-third	5 up, 5 down
Deflected as elevators, two-thirds up	$13\frac{1}{3}$

The differential deflections of the elevons resulting from lateral stick displacements are added algebraically to the elevon deflection resulting from longitudinal stick displacements. All tests were performed with the model in the clean condition (cockpit closed, flaps neutral, and landing gear retracted) and in an erect attitude.

RESULTS AND DISCUSSION

The results of the investigation are presented in charts 1 to 4. Right and left spin results are similar and the results are arbitrarily presented in terms of right spins.

When the loading was chiefly along the wings (chart 1) the model generally would not spin for either tail configuration when the ailerons were neutral or against the spin (stick left in a right spin) regardless of elevator setting. When the elevators were full down and ailerons full against, a spin from which recovery was slow was indicated as possible; this spin was probably attributable to the large downward setting of the inboard elevon. Neither tail configuration was adequate in terminating the spin satisfactorily at the "criterion condition" by rudder movement alone, although movement of the elevators to neutral or down was indicated to be effective. If ailerons were allowed to remain full with the spin, satisfactory recovery was not possible.

When the loading was chiefly along the fuselage (chart 2), the aileron effect was reversed and ailerons against the spin led to poor recovery characteristics whereas ailerons full with the spin led to rapid recoveries for either tail configuration. The results indicated that neither tail configuration would satisfactorily terminate the spin from the "criterion condition." A few brief tests made with the elevons set to simulate an increased elevator-up setting indicated a favorable effect.

In an attempt to increase the effectiveness of the vertical tails in a spinning attitude both the single and twin tails were moved longitudinally rearward by increasing the tail lengths by approximately one-third. As indicated in chart 3, there appeared to be little effect of this change for either tail when the mass was distributed chiefly along the wings. When, however, the mass was distributed chiefly along the fuselage (chart 4) satisfactory recovery characteristics were obtained for both tail configurations. This result is in general qualitative agreement with the criterion for vertical-tail design requirements for airplanes having horizontal tails (reference 4).

CONCLUSIONS

Based on an investigation of a model of a swept-wing fighter type of airplane with no horizontal tail and having either a single vertical tail on the fuselage or twin vertical tails on the wings, it may be stated that:

1. For loadings in which the mass was distributed chiefly along the wings, neither design was adequately effective in satisfactorily terminating the spins by rudder movement alone, and satisfactory recovery from the spin was contingent upon use of elevator or ailerons.

2. For loadings chiefly along the fuselage, both tail designs led to satisfactory spin recoveries if the vertical tails were located at a rearward position.

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REFERENCES

1. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. NACA Rep. 557, 1936.

2. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting The Effect of Control Manipulation on the Recovery from a Spin. NACA ARR, Aug. 1942.

3. Berman, Theodore: Comparison of Model and Full-Scale Spin Test Results for 60 Airplane Designs. NACA TN 2134, 1950.

4. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN 1045, 1946.

TABLE I

FULL-SCALE DIMENSIONAL CHARACTERISTICS OF A FIGHTER

TYPE OF AIRPLANE AS REPRESENTED

BY THE MODEL $\left(\frac{1}{20}\text{ SCALE}\right)$

Fuselage length, ft	20.45
Wing:	
Span, ft	26.83
Area, sq ft	200.00
Incidence (root and tip), deg	0
Aspect ratio	3.60
Sweepback (at quarter-chord line), deg	38.1
Dihedral	0
Elevons:	
Span, percent of wing semispan	45.4
Vertical tail (single) volume, ft^3 (area of surface times tail length):	
For tail in original position	188
For tail moved rearward	244
Vertical tail (twin) volume, ft^3 (area of surface times tail length):	
For tails in original position	192
For tails moved rearward	259

TABLE II

MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADING CONDITIONS TESTED ON A MODEL

$\left(\frac{1}{20} \text{ SCALE}\right)$ OF A FIGHTER AIRPLANE

[Model values converted to corresponding full-scale values; moments of inertia are given about center of gravity]

Loading	Weight (lb)	Airplane relative density, μ		Moments of inertia (slug-ft^2)			Inertia parameters		
		Sea level	Test altitude (15,000 ft)	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
1 Chiefly along wings	6815	16.59	23.36	3910	2749	6534	76×10^{-4}	-249×10^{-4}	173×10^{-4}
2 Chiefly along fuselage	6815	16.59	23.36	2381	3787	6041	-92×10^{-4}	-148×10^{-4}	240×10^{-4}

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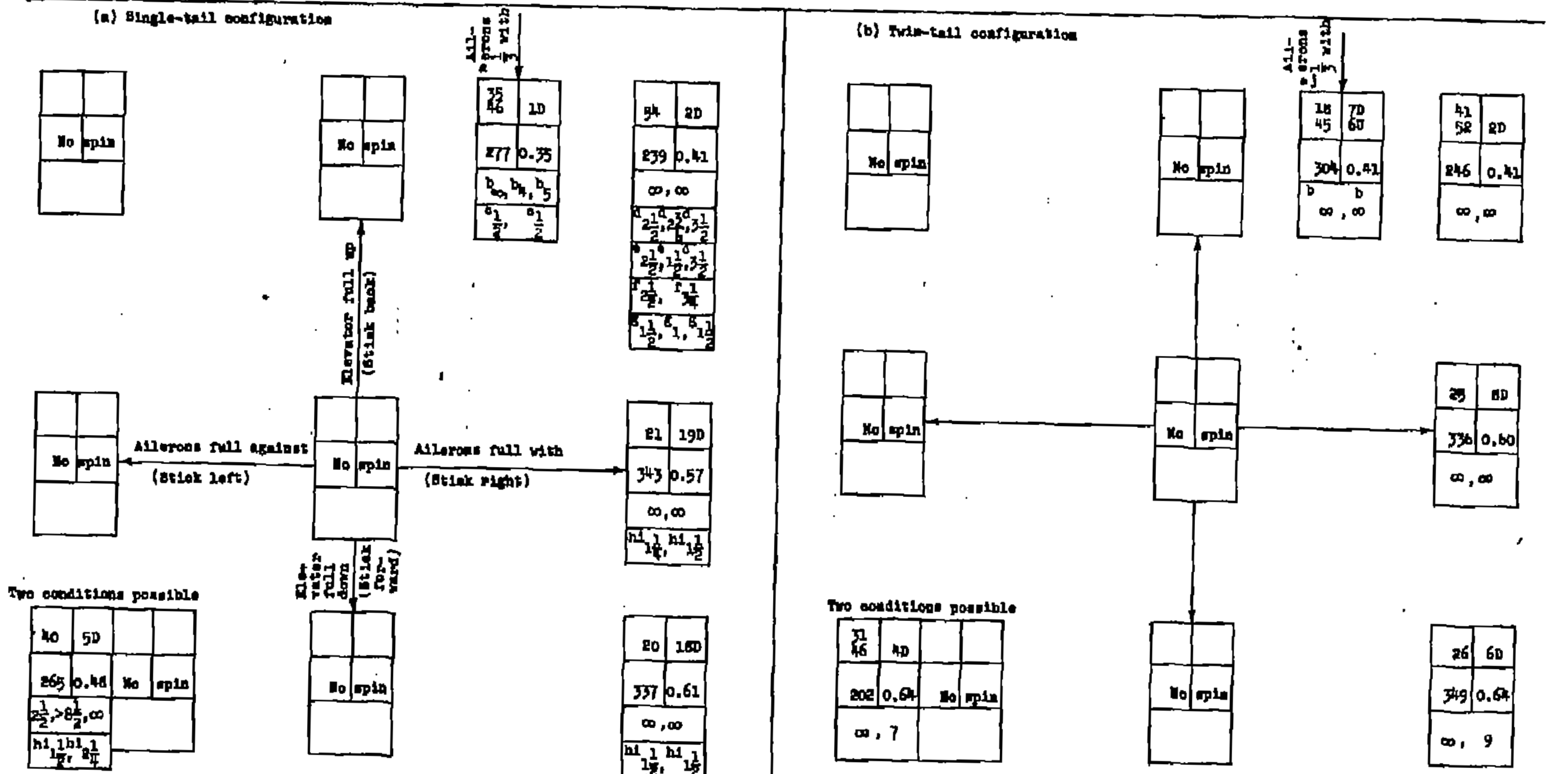
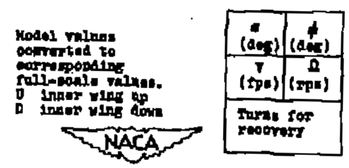
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL LOADED CHIEFLY ALONG THE WINGS

[Loading point 1 in table II and figure 5; recovery attempted from and steady-spin data presented for rudder-with spins to the pilot's right; recovery by rapid full rudder reversal unless otherwise stated]





[a] Model oscillatory in pitch.

[b] Recovery attempted by movement of rudder from full with to two-thirds against the spin.

[c] Recovery attempted by neutralization of the elevators.

[d] Recovery attempted by simultaneous reversal of rudder and elevators.

[e] Recovery attempted by simultaneous neutralization of the rudder and ailerons.

[f] Recovery attempted by simultaneous neutralization of elevators and ailerons.

[g] Recovery attempted by simultaneous reversal of the rudder and movement of the ailerons full against the spin.

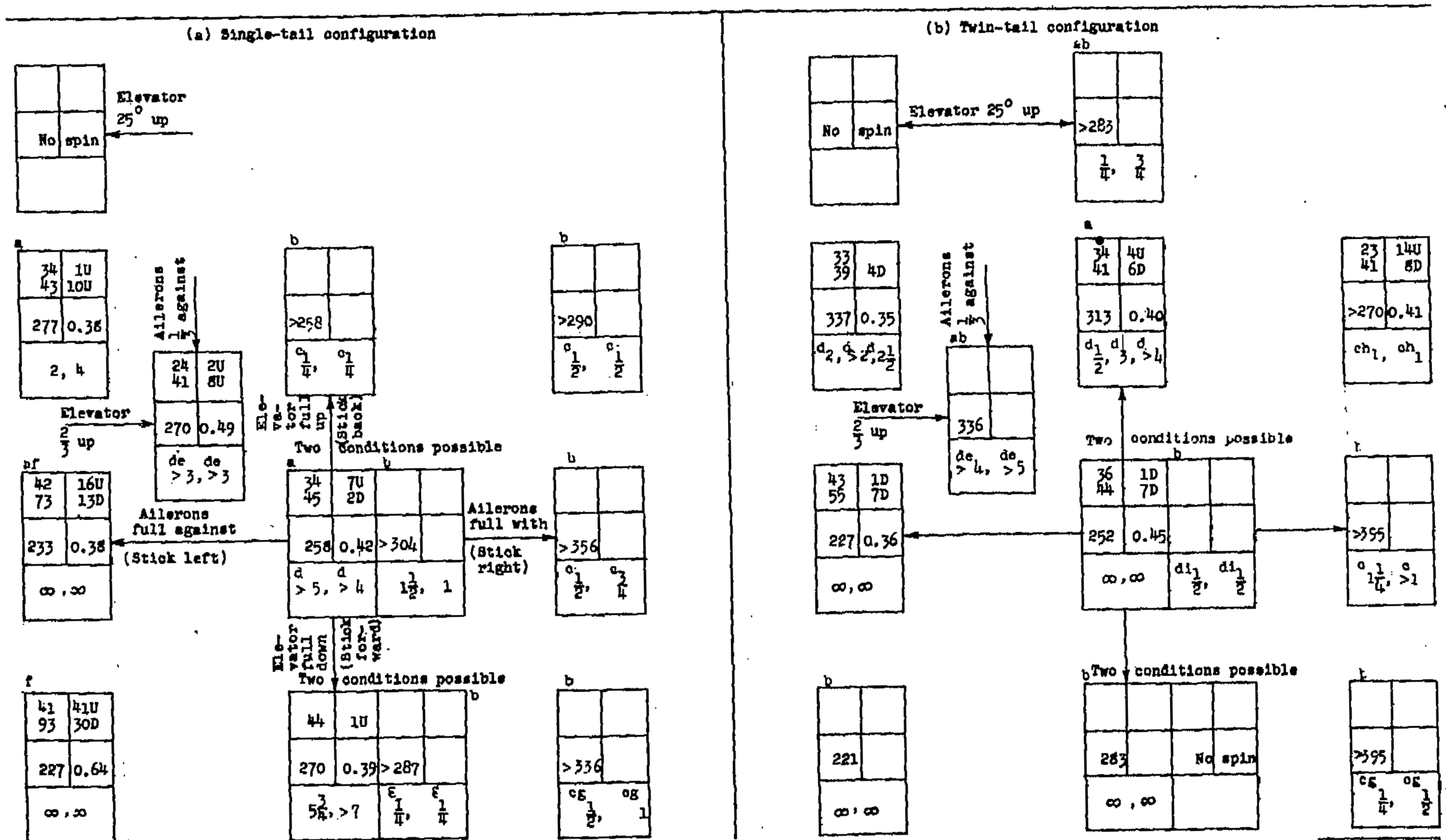
[h] Recovery attempted by neutralization of the ailerons.

[i] Model recovers in an inverted dive.

[j] Wandering spin.

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL LOADED CHIEFLY ALONG THE FUSELAGE

[Loading point 2 in table II and figure 5; recovery attempted from and steady-spin data presented for rudder-with spins to the pilot's right; recovery by rapid full rudder reversal unless otherwise stated]



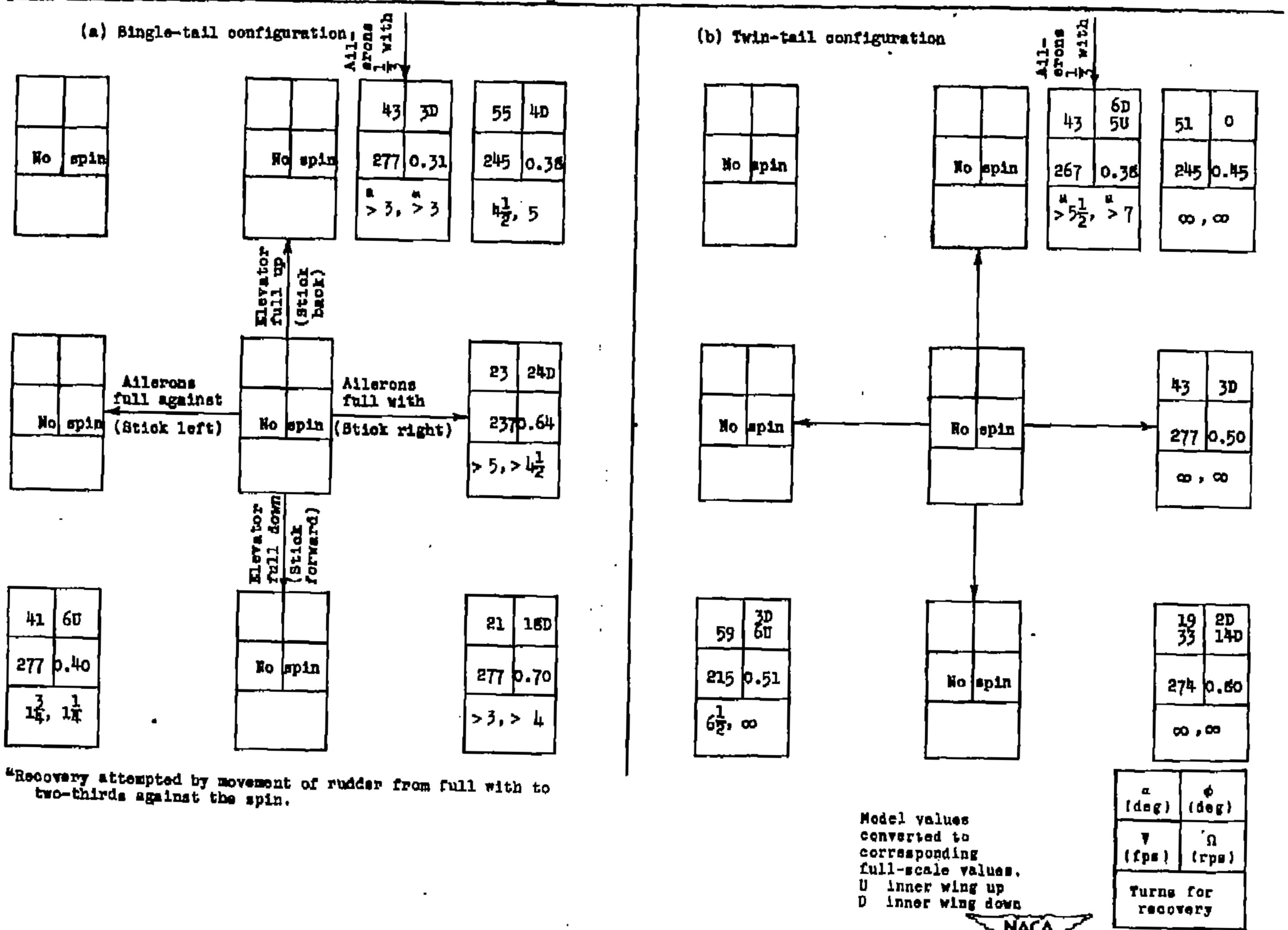
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

[a]Wandering spin.
[b]Steady spin data not available.
[c]Recovery attempted before model reached final attitude.
[d]Visual observation.
[e]Recovery attempted by movement of the rudder from full with to two-thirds against the spin.
[f]Model oscillatory in roll, pitch, and yaw.
[g]Model recovers in an inverted dive.
[h]Upon recovery model goes into a wide spiral.
[i]Steep spin.

CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL LOADED CHIEFLY ALONG THE WINGS.
SINGLE AND TWIN VERTICAL TAILS MOVED REARWARD.

[Loading point 1 in table II and figure 5; recovery attempted from and steady-spin data presented for rudder-with spins to the pilot's right; recovery by rapid full rudder reversal unless otherwise stated]



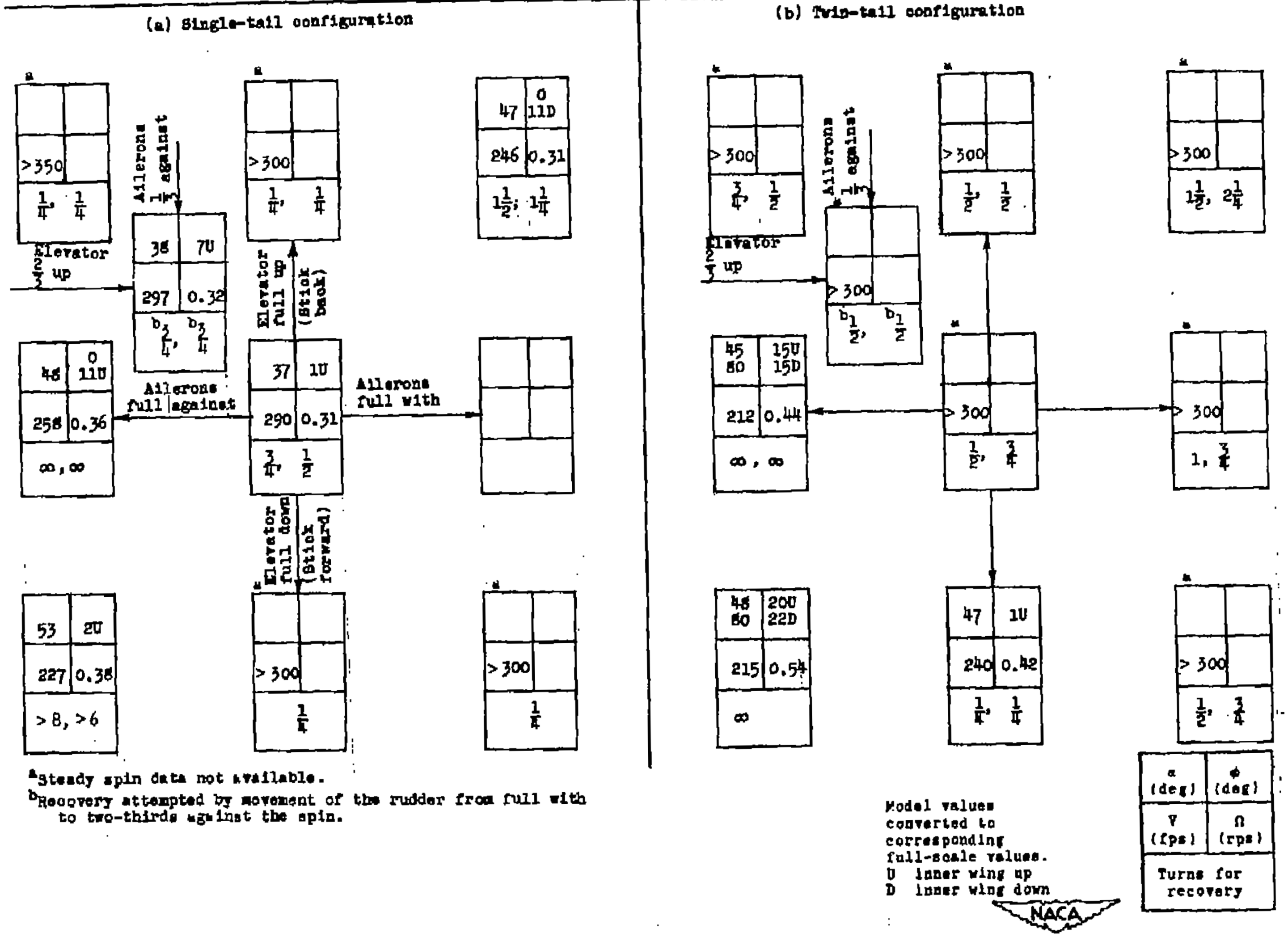
ᵃRecovery attempted by movement of rudder from full with to two-thirds against the spin.

[redacted]

[redacted]

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL LOADED CHIEFLY ALONG THE FUSELAGE. SINGLE AND TWIN VERTICAL TAILS MOVED REARWARD.

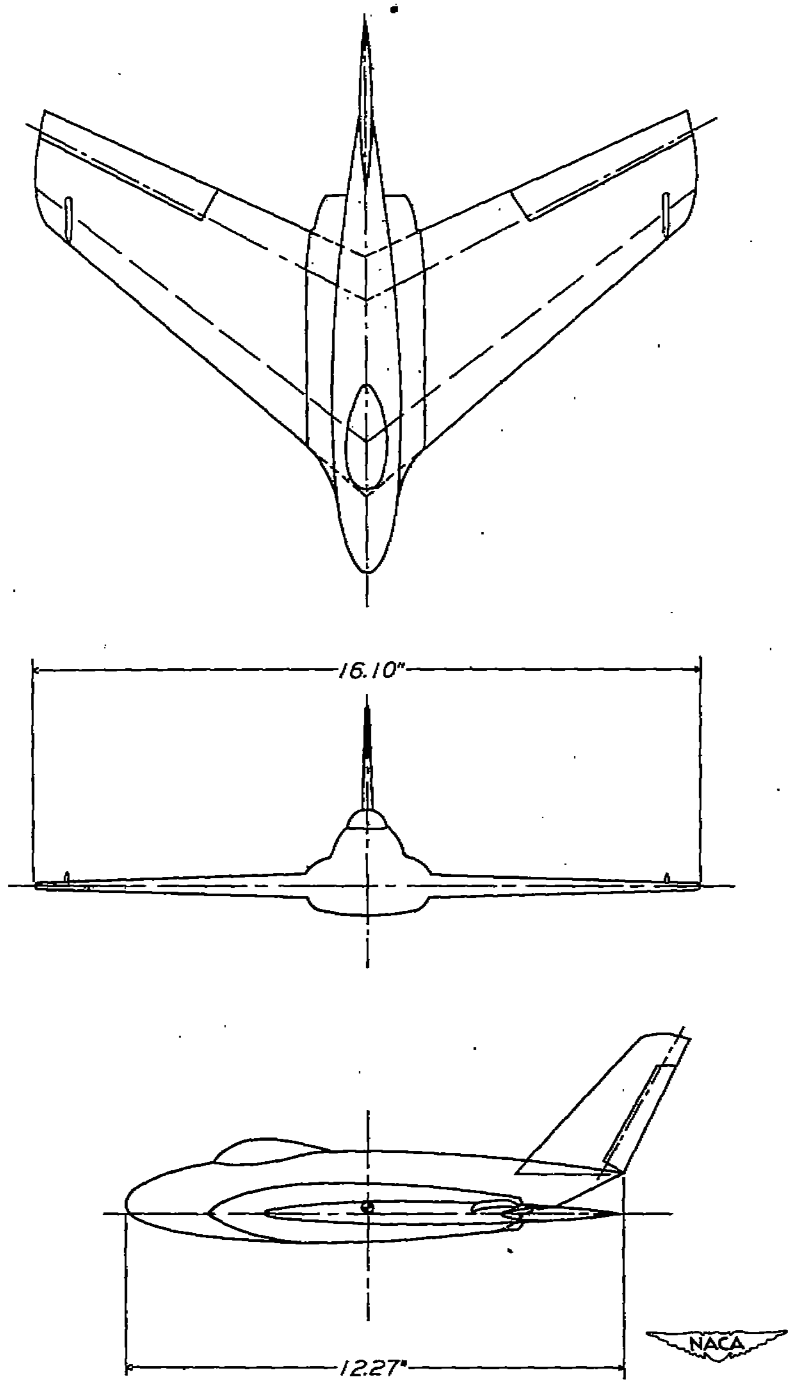
[Loading point 2 in table II and figure 5; recovery attempted from and steady-spin data presented for rudder-with spins to the pilot's right; recovery by rapid full rudder reversal unless otherwise stated]



[a]Steady spin data not available.

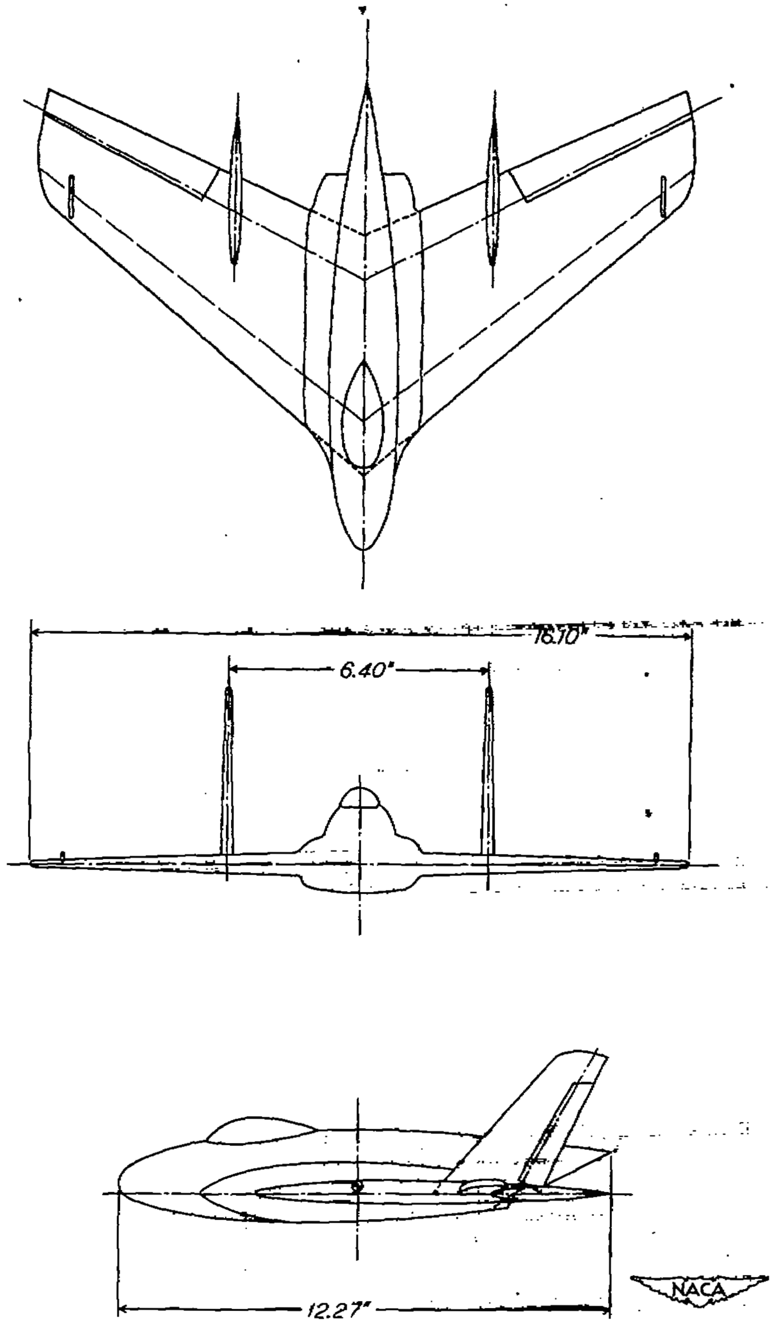
[b]Recovery attempted by movement of the rudder from full with to two-thirds against the spin.

[redacted]



(a) Single-tail configuration.

Figure 1.- Model tested in Langley 20-foot free-spinning tunnel.



(b) Twin-tail configuration.

Figure 1.- Concluded.

[redacted]

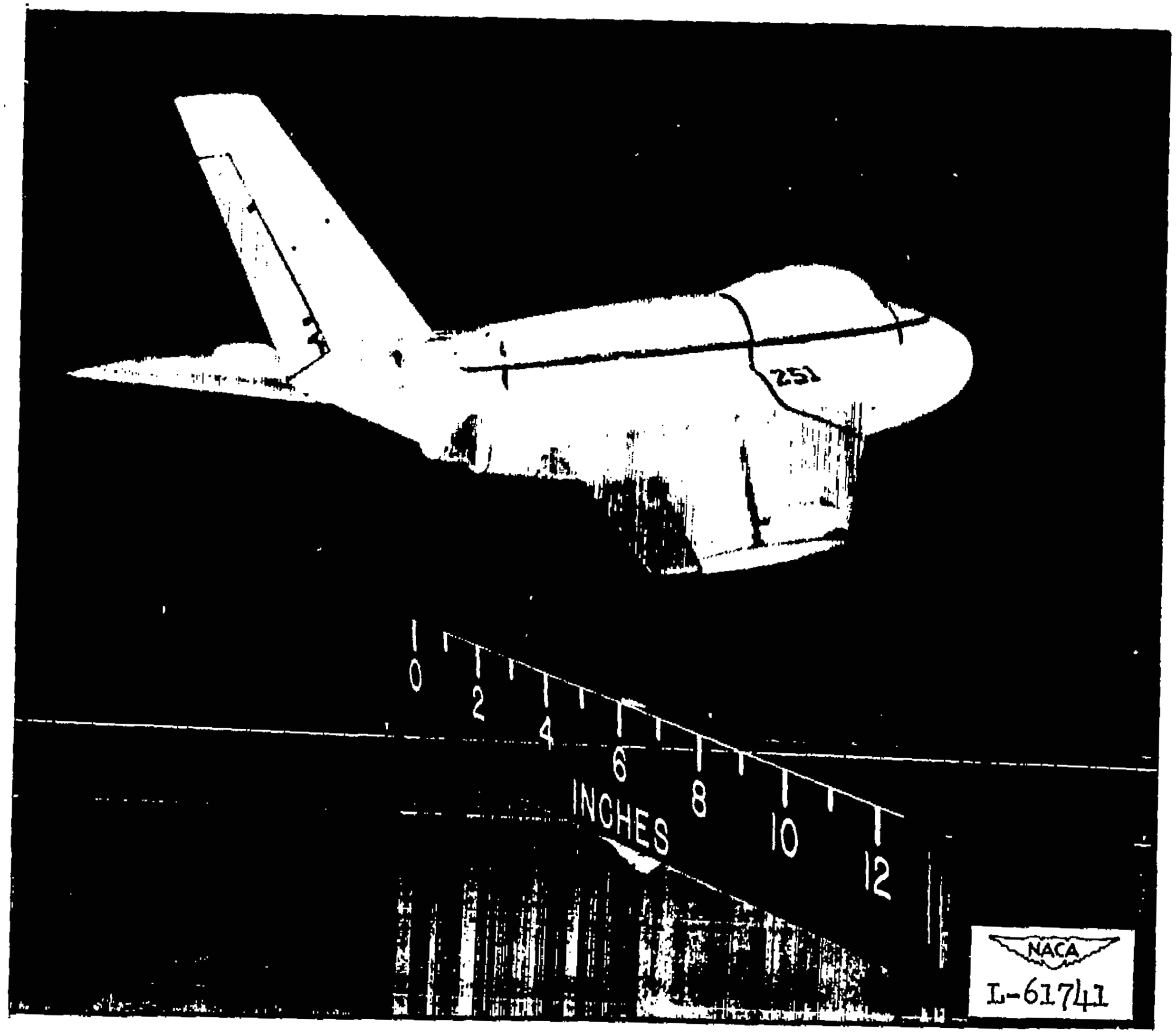
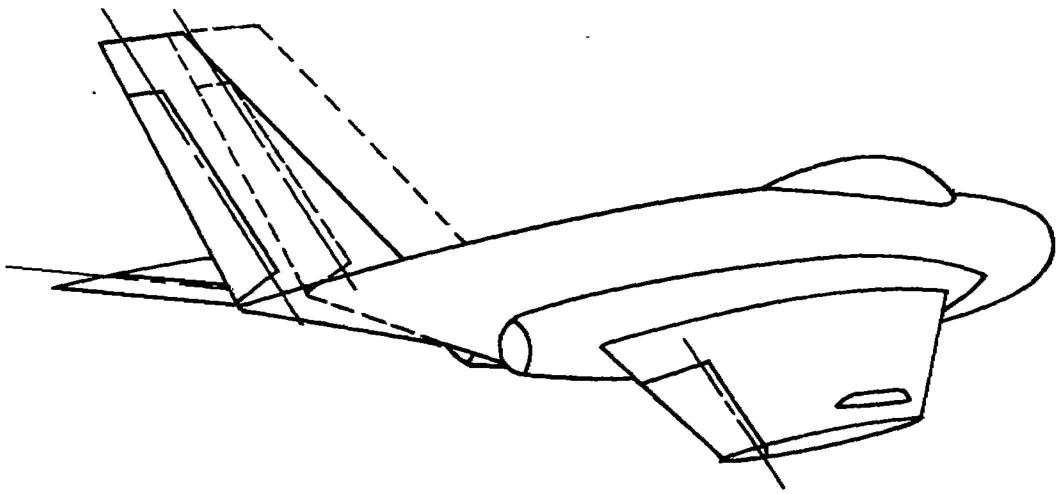
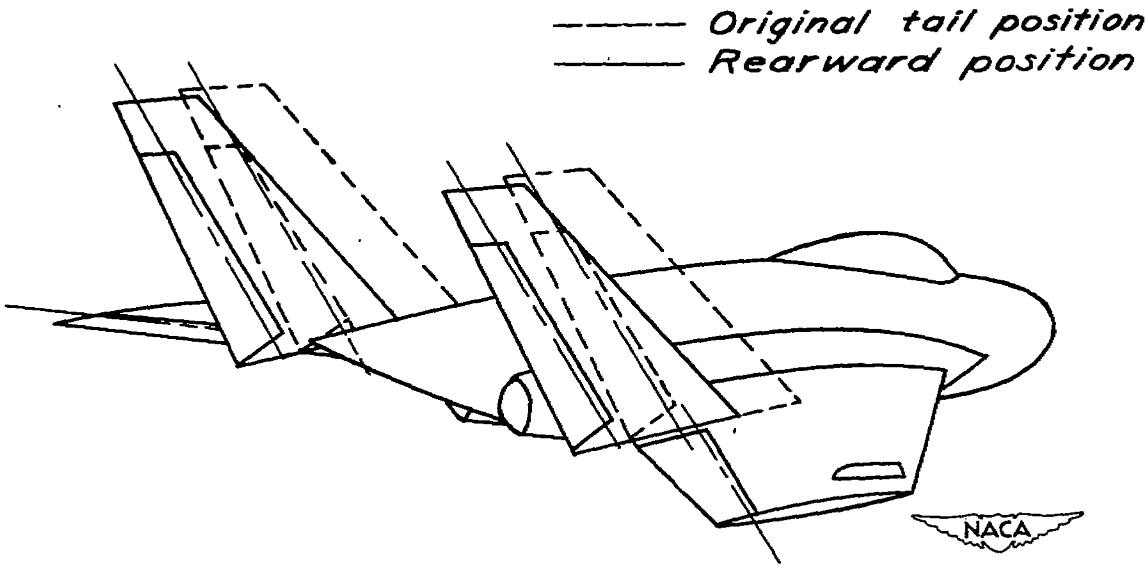


Figure 2.- Model with a single vertical tail installed on the fuselage.



(a) Single-tail configuration.



(b) Twin-tail configuration.

Figure 3.- Model with single and twin vertical tails installed in both the forward and rearward positions.

Figure 4.- Model spinning in the Langley 20-foot free-spinning tunnel.

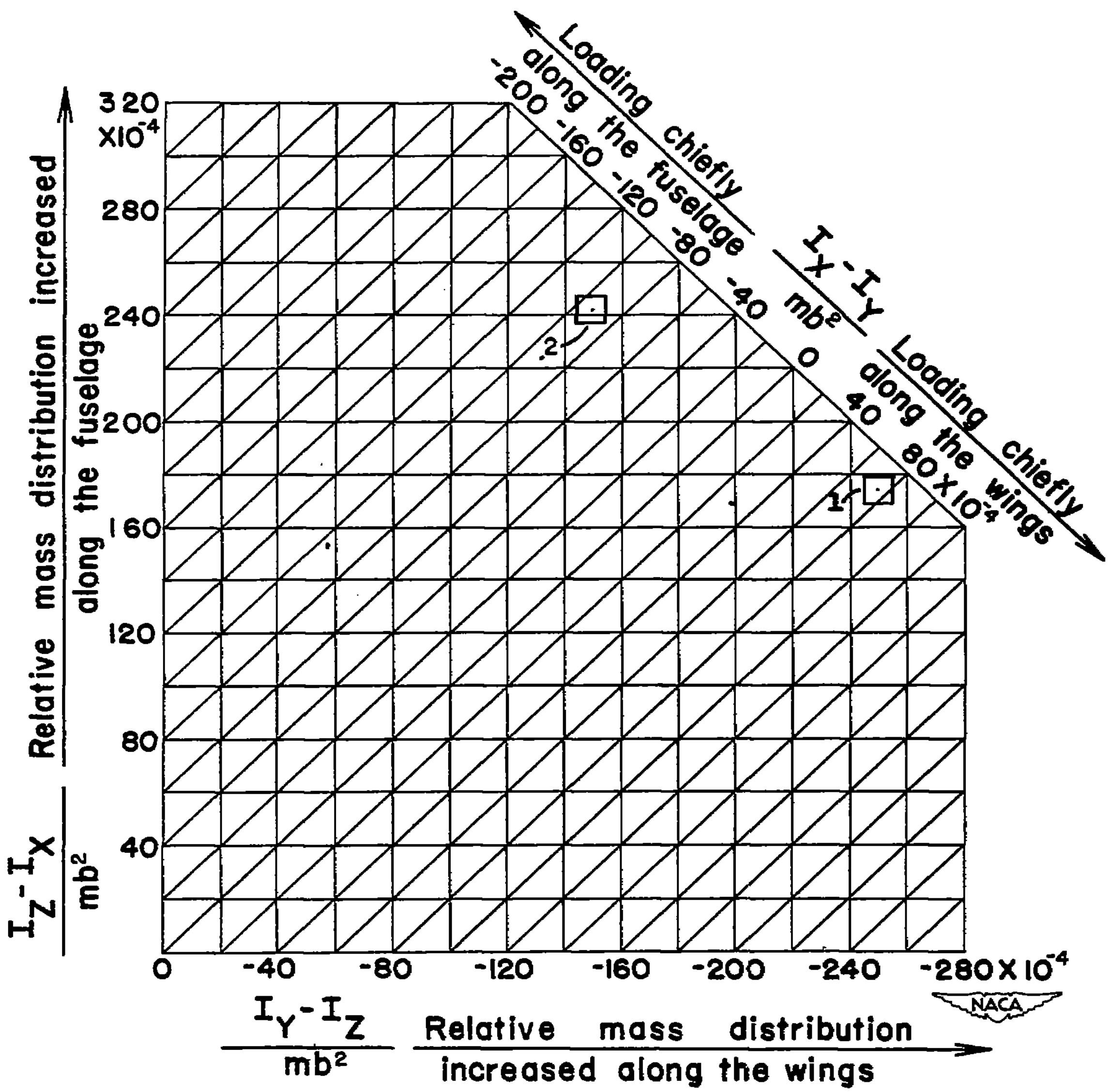


Figure 5.- Inertia parameters for loadings tested on the model (points are for loadings listed in table II).